ELASTICITY OF MONEY AS A REINFORCER: ASSESSING MULTIPLE COMPOSITIONS OF UNIT PRICE

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Behavioral economics is the integration of concepts from micro-economics into behavior analysis. Most of the research in behavioral economics has been done with non-human subjects and with drugs as reinforcers. This study represents an extension of previous research to assess money as a reinforcer with humans as subjects. The participants in this study solved math problems to earn money at various unit prices. Results indicate that demand of money adhered to the law of demand in that consumption decreased as unit prices increased. An underlying assumption is that consumption should be equivalent at different compositions of unit price. Replications of either the same or different compositions of unit price indicated that there were some discrepancies in consumption in this study.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF ILLUSTRATIONS

Page

CHAPTER 1

INTRODUCTION

Behavioral economics is a relatively new sub-discipline of behavior analysis that concentrates on the factors controlling the allocation of behavior among available reinforcers (Hursh, 1980; 1984; 1993). The assumptions underlying the theory of behavioral economics rest on findings from microeconomic research and the theory of supply and demand. Concepts like consumption, demand, income, price, elasticity, and substitutability have been adopted and fitted into the operant paradigm. Specifically, in the case of price, work requirements and reinforcing consequences are thought to conform to one common variable. This implies a unified account of two variables previously thought to act independently of each other in behavior analysis. In discussing the contributions of behavioral economics Bickel, Green and Vuchinich (1995) stated:

> Economics provides a rich area of knowledge and conceptual elegance that offers new independent variables, methods of analysis, and dependent measures. New independent variables such as income and open and closed economies suggest a new view of choice and schedule performance; new methods of analysis such as unit price permit a parsimonious integration of multiple interacting variables and, importantly, specify mathematically how those variables interact; new measures such as elasticity (proportional change in consumption as a function of increasing price) and substitutability measure different features of reinforcers, ones that

> might be useful in comparing reinforcing events. These and other economic concepts and measures also motivate alternative theoretical conceptualizations of how reinforcers influence behavior and compel the consideration of new applications and techniques for behavior change. (p. 257)

This statement summarizes some of the major contributions of a behavioral economic analysis to the understanding of operant behavior. “Not very surprisingly, laboratory experimentation based on behavioral analysis has proven to be the most powerful method for defining, testing, and refining economic theory” (Hursh & Bauman, 1987). With price as an important concept, the study of choice among events functioning as reinforcers in behavioral studies becomes analogous to consumers choosing between different commodities. Whereas in economics consumption is regarded as a function of the monetary cost of a commodity relative to the benefit of its consumption, economics in a behavioral realm focuses on response outputs, typically in terms of responding on various schedules of reinforcement.

Early research on behavioral economics looked at essential commodities such as food and water. Later, behavioral economic analyses have been utilized predominantly in studies examining the pharmacological effects of drugs and illegal substances in both non-humans (e.g., Carroll, Carmona, & May; 1991; Lemaire & Meisch, 1984) and humans (e.g., Bickel, DeGrandpre, Hughes, & Higgins, 1991; Bickel, Hughes, DeGrandpre, Higgins, & Rizzuto, 1992). In behavioral economics studies, drug self-administration is treated as operant behavior. Behavioral economic analyses are consistent with the view that the sensitivity of behavior to contextual constraints (i.e., price) is the same for different drugs and for non-drug reinforcers (see, Green, 1986) and that all operant behavior can be analyzed in a cost-benefit paradigm. When viewed as choice, drug taking and drug dependence become issues of understanding how qualitatively different reinforcers interact with each other when concurrently available (Bickel, DeGrandpre, & Higgins, 1995).

Quantitative methods of behavioral economics consider drug and context to be equally important variables. As such, the two most widely studied variables in drug self-administration studies have been response requirements and drug doses. Data have shown that increasing requirements typically decrease consumption while increases in dose typically first increase then decrease the number of drug self-administrations (DeGrandpre & Bickel, 1996). In economics, the terms “consumed” or “consumption” typically refer to how much an organism buys or obtains of a commodity, not how much is in fact used or eaten. Likewise, “consumption” in behavioral economics, refers to how many units of a reinforcer an organism obtains during an experimental period. The term “commodity” is used interchangeably with the term “reinforcer”. “Commodity” is preferred, however, because it does not carry the empirical burden of having to increase rates of responding above a predetermined operant level. This distinction becomes important as consumption is assessed at high costs or response requirements.

How an organism allocates its behavior depends on many factors. For example, the quality or quantity of the reinforcer, the cost of the reinforcer (i.e., the response requirement for obtaining the reinforcer), access to the reinforcer over periods of time, the presence or absence of alternative reinforcers, or the probability or delay of the reinforcer may all influence the rate at which the organism consumes (i.e., obtains) the reinforcer. These are all variables that behavioral economics considers in an account of choice behavior. Behavioral economics has, therefore, provided a new and useful conceptualization for analyzing behavior (Hursh, 1980). The focus of this conceptualization is on how environmental events affect demand for a reinforcer and how these effects on demand are altered by the context in which these environmental events occur (DeGrandpre & Bickel, 1996). The following sections will discuss issues such as unified variables, contextual influence, ability to predict choice, reinforcer demand, elasticity, substitutability, economy, income, and unit price.

According to Hursh (1993): "One of the most important contributions of behavioral economics has been to redirect our attention to total daily consumption as a primary dependent measure of behavior" (p.166). Rate of responding is a primary measure in reinforcement theory, whereas total responding or work rate output is considered a secondary dependent measure in behavioral economics. Hence, there has been a shift from looking at the impact of different schedules of reinforcement on rates of responding, to a focus on total consumption as a function of work rate under various contextual constraints.

Based on a theoretical assumption of maximization of utility or value (which implies defense of consumption as an important factor controlling behavior), the organism is thought to adapt to the prevailing constraints of the environment. This approach has yielded changes in methodology and has directed our attention to new variables previously ignored and functional relations previously unexamined (Hursh, 1993). For example, several studies have re-analyzed data from earlier studies and found that reinforcer-magnitude manipulations and schedule manipulations interact in a manner that can be quantified in terms of a single variable. The two variables are thus functionally equivalent (e.g., Bickel, DeGrandpre, Higgins, & Hughes, 1990; DeGrandpre, Bickel, Hughes, Layng, & Badger, 1988). These studies have shown that data previously interpreted as schedule effects on rate of responding in reinforcement theory can be better and more fully understood as consumption under contextual constraints. Hursh and Bauman (1987) pointed out that operant research has implicated a number of important variables such as rate, probability, immediacy of reinforcement, amount and quality of reinforcement, and availability of alternative sources of reinforcement. Utilizing economic factors that parallel these variables may provide a more complete understanding of the variables and the interactions that affect reinforcement and response rate.

The interacting effects of environmental variables are, conceivably, important aspects that traditional operant research has failed to acknowledge. For example, Bickel et al. (1990) re-analyzed data from several experiments and showed that drug consumption by animals under a variety of conditions was a decreasing function of price (responses/dose of drug). DeGrandpre, Bickel, Hughes, and Higgins (1992) reported similar findings in a study re-analyzing data from nicotine-regulation studies in humans. It was also reported that the behavioral economic re-analysis showed less variability in the data across regulation studies than was originally reported. DeGrandpre et al. concluded that the behavioral economics approach brings unity to variable sets of data, and makes better quantifications. Furthermore, behavioral economics provides a more parsimonious interpretation of data and contextual variables that generalizes to other drug- and food-maintained behaviors in humans as well as non-humans, and integrates behavioral and pharmacological factors that control the consumption of reinforcers. These are important generalizations that have been empirically supported across a range of studies assessing different reinforcers in humans as well as non-humans.

A central concept that behavioral economics has adopted from microeconomics is the notion of supply and demand. “In behavioral economics terms, demand for a commodity is defined as the change in consumption as a function of change in price” (Carroll et al., 1991, p.374). Hursh and Bauman (1987) explain that demand is determined across a range of prices and the response rate is determined by an equilibrium point at each price. A general finding in behavioral economic studies has been, as previously mentioned, that consumption decreases as price increases (i.e., there is an inverse relation between price and consumption). In other words, consumption typically varies directly with the utility or value of different demand and supply bundles (see Green, Kagel, & Battalio, 1982). A cost-benefit process is said to be controlling consumption. The total effect of price on consumption has, however, shown to be a factor of several contextual factors. This will be discussed in more detail later. Supply and demand theory is primarily concerned with analyzing and predicting changes in work-consumption packages resulting from changes in constraints (Green et al., 1982).

The relationship between various levels of reinforcer cost and reinforcer consumption is analyzed as a demand curve (see Hursh, 1993). Demand curves provide a basis for quantifiable assessment of multiple variables in concert. Typically, in demand curves, consumption has been shown to decrease with increasing price (see Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). Hursh and his colleagues also found that their demand curves were smooth with gradual decreases in consumption across increases in price. Similar demand curves have been demonstrated in several studies assessing consumption across varying prices. Another common attribute of a demand curve is that maximum consumption of a commodity (e.g., a drug) is found at the smallest response requirement and the highest concentration or amount of the reinforcer (e.g., Macenski & Meisch, 1998).

Several studies have demonstrated the utility of the demand curve in predicting consumption at various prices (e.g., Bickel et al., 1992). Some exceptions exist, however, particularly in studies utilizing drugs as reinforcers. For example, some studies have documented the ability to predict consumption at larger doses but failure to do so at similar prices consisting of smaller doses of the drug reinforcer (e.g., Marquis, Webb, & Morton, 1989; Van Etten, Higgins, & Bickel, 1995; Winger, 1993; Woolverton, English, & Weed, 1997). Similarly, demand curves have failed to predict consumption in some cases where direct drug effects have been hypothesized to be the cause for inconsistencies (Carroll et al., 1991).

The behavioral economics paradigm has, however, demonstrated a broad applicability in a wide array of contextual constraints. Its contextual approach shares some common features with the findings of the matching law. Herrnstein (1961) first officially acknowledged the importance of the context in which choice take place. In this study, pigeons chose between two response keys, each producing independent delivery of food pellets on concurrent variable-interval (VI) schedules. It was reported that with several values of VI schedules, the proportions of responses to a key matched that of the relative proportions of reinforcement that were delivered for pecking the keys. This phenomenon has come to be called ‘matching’. Not only did Herrnstein demonstrate the importance of context during choice, but this analysis also allowed for quantification leading to better prediction and control of behavior in choice situations (see Skinner, 1953, 1974). Herrnstein (1961) proposed the equation

$$\frac{P1}{P1 + P2} = \frac{r1}{r1 + r2} \qquad (1)$$

where P1 and P2 are the numbers of pecks on key 1 and key 2 and r1 and r2 are the rates of reinforcement delivered on key 1 and key 2. When similar values are found for both equations, the relative rates of responding are said to match the relative rates of reinforcement.

Herrnstein (1970) further demonstrated that any situation can be conceived as a choice situation. The matching law predicts that a given response is influenced not only by the reinforcers contingent upon it but also by other reinforcers within the situation even when such choices do not appear as discrete. Hence, any behavior can be conceived as choice behavior. This focus on all behavior as choice is also the essence of the behavioral economic approach (see Rachlin, Battalio, Kagel, & Green, 1981). This has implications for an understanding of behavior on single schedules of reinforcement as well. For example, in a procedure in which a pigeon responds on a single schedule of reinforcement, the pigeon has the choice to respond on the key or engage in any other activity (e.g., preening). Herrnstein was able to demonstrate that reinforcement obtained by engaging in behaviors other than pecking the key needed to be included in a mathematical prediction model of behavior. Essentially, Herrnstein's (1970) equation (not given here) demonstrates the important role of alternative sources of reinforcement in any given situation.

The main similarity between behavioral economics and the matching law rests on their underlying assumptions of contextual influence on choice. Both theories assume that choice takes place in a setting of constraints and both assume that molar mechanisms govern choice (with some exceptions). However, behavioral economics and matching differ in some aspects, such as their generality in predicting choice. One of the shortcomings of the findings from the application of matching equations to responding on concurrent choice schedules has been their difficulty in predicting choices among qualitatively different reinforcers (Green & Freed, 1993). Matching law studies predominantly have been restricted to studies of qualitatively similar reinforcers (e.g., food/food or drugs/drugs) whereas behavioral economics research has included research on a variety of qualitatively dissimilar commodities like food and water (Hursh, 1978), electrical brain stimulation and food (Hursh & Natelson, 1981), and cocaine and methohexital (e.g., Winger, 1993) to name a few examples.

Hollard and Davison (1971) and Miller (1976), however, did demonstrate that matching could occur on concurrent VI/VI schedules with qualitatively different reinforcers. Hollard and Davison (1971) obtained matching in pigeons responding for food and electrical brain stimulation (EBS), where EBS was kept constant while rate of food reinforcement availability was varied in an open economy. Miller (1976) reported matching in pigeons pecking to obtain hemp, buckwheat, or wheat grains in pairwise presentations. Miller was able to predict choices based on scaling of value of the three different types of grains. Time-based scaling predictions were more accurate than behavior based predictions. Matching previously has been demonstrated to pertain to rate of responding as well as with of time allocation (see Baum & Rachlin, 1969).

Green and Freed (1993) point out a problem with efforts to scale commodities according to their value stating that scaling of reinforcers is done independently of context. Green and Freed (1998) extend this point in a discussion of the findings from Green and Rachlin (1991). Green and Rachlin found that the pairwise combinations of either food, water, or EBS resulted in substitutability of food and water for EBS. When food and water were paired, water was not substitutable for food. If reinforcer interactions are transitive, then, because food and water are each substitutable for EBS, one would predict that food and water should be substitutable for each other. This was not the case and may therefore demonstrate a counterpoint to the findings of Hollard and Davison (1971) and Miller (1976). Scaling and transitivity of interactions among reinforcers that are less than perfect substitutes becomes problematic. This implies that goods that are scaled in combination may take on dissimilar characteristics when presented separately or in different contexts. Bickel and colleagues (1992) also reported similar findings with humans as subjects. In this study, increases in the price of cigarettes (and a subsequent decrease in consumption) resulted in a decrease in consumption of coffee whereas increases in the price of coffee did not affect the consumption of cigarettes. Rachlin, Kagel, & Battalio (1980) also point out some of the problems of scaling reinforcer value independent of context (such as the need to include a new parameter to the matching equation). Nevertheless, the fact remains that scaling and prediction of choice behavior was obtained in the study by Miller (1976). The generality of these findings have, however, not been extended in subsequent research. The fact seems to remain that matching equations do not satisfactorily predict choices among qualitatively different reinforcers.

If one assumes the matching relation to be valid, some other factor must be incorporated to preserve the relation between relative obtained reinforcement value and relative amount consumed for qualitatively different reinforcers (Green & Freed, 1993). In other words, the matching law becomes too narrow an account for a general model of choice. Behavioral economic theory, on the other hand, has proven to be a suitable paradigm for such an analysis of choice. Research utilizing the behavioral economics paradigm has been able to demonstrate lawful relations with qualitatively different commodities as well as demonstrations of elasticity of demand as a function of various contextual constraint manipulations. The scope and the breadth of an analysis of choice is therefore enhanced.

Assessing and comparing qualitatively different reinforcers implicitly brings attention to the concept of value. Consumption at a very low price may give a skewed picture of reinforcer value if one compares the same commodities at higher prices (e.g., see Tustin, 1994, where a crossover in demand occurred between two commodities compared at low and high prices). Hursh and Natelson (1981) found that rats responding for concurrently available food and electrical brain stimulation (EBS) consumed high relative amounts of EBS and low amounts of food at low prices. The "value" of EBS decreased proportionally with increases in price while food consumption remained steady throughout the experiment despite increases in price. In situations where consumption of a commodity is gradually surrendered as price increases, the commodity is said to be elastic. These goods can, for example, be different luxuries. When consumption remains steady despite increases in price, demand is said to be inelastic. These goods are typically necessities. Food, in the Hursh and Natelson study, was shown to be inelastic. Hence, elasticity is said to be the degree to which consumption of a commodity is affected by changes in price (Green & Freed, 1993).

In economics terminology, elasticity as measured by performance change is distinct from reinforcer value as measured by performance output in a single defining situation (Hursh & Bauman, 1987). Elasticity is a measure of how sensitive consumption is to the imposed constraints, and by implication, of how responding adapts to those constraints (Hursh, 1980). When looking at a demand curve, consumption is viewed across multiple price manipulations. Thus, the behavioral economic model emphasizes responding maintained by a reinforcer at more than one response requirement or cost (Foltin, 1994). Elasticity of demand therefore becomes synonymous with reinforcer value.

Elasticity can be assessed as both own-price elasticity and cross-price elasticity depending on the context in which prices are manipulated. Changes in consumption can be graphed across changes in prices of the commodity itself. This is referred to as own-price elasticity. Cross-price elasticity is assessed when consumption is plotted against changes in price of some other commodity present in the situation. Hence, cross-price elasticity suggest a means of investigating reinforcer interactions in a way similar to that of the matching law (Green & Freed, 1998) in the sense that responding shifts between the relative reinforcing outcome between two or more alternatives. Own-price demand curves represent a measure of absolute reinforcement value.

From the standpoint of behavioral economics, the molar concept of demand elasticity substitutes for the typical measures of reinforcer value such as rate and probability of responding. Demand for a commodity does not have a fixed or inherent degree of elasticity but rather varies across different contextual manipulations and defines a rather flexible continuum. Furthermore, elasticity is typically not linear in the sense that consumption is usually less sensitive to relative changes at low prices and more sensitive to similar relative changes at higher prices. The demand for a commodity can be both inelastic and elastic in the same demand curve if it is insensitive to changes in price up to a certain point before consumption starts decreasing with further increases in price. This is referred to as mixed elasticity and is commonly seen when a demand curve for a commodity is drawn across a range from low to high prices. Overall, elasticity is determined by a multitude of factors and can vary not only within a single demand curve, but also as a function assessing demand at different points in time (e.g., as income or economy is altered over time). It is therefore apparent that elasticity of demand is not an absolute quality of a commodity but is relative to other commodities and contextual constraints.

Let the following scenario be an attempt to explain an example of the plasticity of elastic demand from a hypothetical case of drug abuse. Most recreational drugs are characterized by elastic demand. For a beginning drug abuser, consumption of a recreational drug will not be defended at relatively high prices. However, as the drug abuse continues, tolerance to the drug may increase and higher doses may be required to get the previous effects. This may be conceived as an increase in unit price since more drugs have to be consumed to obtain the previously experienced effects. It is under this kind of circumstances that addictions may be thought to develop. As the person gets addicted to a drug, we may infer that the drug consumption becomes more inelastic (i.e., consumption is defended at a wider range of prices). In other words, the person who is addicted will pay higher prices (i.e., either in terms of money spent or effort put out to obtain the drug) for the drug than before he/she was addicted (i.e., he/she was a recreational user). The amount of literature on elasticity as a model for the development of drug addiction is scarce but the implications are profound (see Green & Kagel, 1996; Hursh, 1991, for some related issues).

Demand, the consumption of a commodity across changes in price, is closely related to amount of work expended. As long as consumption is defended as the price of a commodity increases, the organism must increase the amount of work to compensate for the increased requirement. The price that produces a maximum level of responding demarcates the boundary from inelastic to elastic demand. Maximum levels of responding simply refers to the point at which the organism invests the highest number of responses for a reinforcer within a given time interval. This point of maximum level of responding is referred to as Pmax (Hursh, 1991). Thus, the greater the general elasticity of a demand curve is, the lower the price at which the peak response output is reached (Hursh & Winger, 1995). Demand with a high Pmax is referred to as inelastic compared to demand with a lower Pmax. The point of Pmax in a work level space (i.e. the space between an x-axis with prices of a commodity and a y-axis with levels of responding) is also dependent on several factors such as the nature of the commodity, type of economy, and income, just to name a few.

Given that the effect of reinforcers can not be understood apart from the context in which they exist, the behavioral economic approach may carry some important implications. Alterations of the reinforcing effect of various commodities as a function of contextual fluctuations constitutes a fundamental feature of behavioral economics. For example, reinforcer substitutability and complementarity can be judged by the degree to which consumption of one commodity changes as the value of an alternative commodity is altered (Green & Freed, 1993). These effects can also be conceptualized as cross-price elasticity (see DeGrandpre & Bickel, 1996). As such, demand is not solely determined by the nature of the commodity, but also the availability of substitutes or other sources of the commodity (see Hursh, 1991).

Bickel et al. (1995) explained that concurrently available reinforcers interact in one of several ways that can be conceptualized as a continuum. At one end of the cross-price continuum is substitutability. Substitutes are characterized by an increase in consumption of one commodity as the consumption of another commodity decreases. For example, Pepsi can, under certain circumstances, function as a substitute when Coke is not available or is relatively more expensive. Worth noting is that magnitude of substitution effects is often a function of the relative prices at which the manipulated and unmanipulated commodities are offered (Bickel et al., 1995). This may be more prevalent the more qualitatively similar the commodities are (as has been repeatedly proven by studies on the matching law). At the other end of the continuum, goods are complements. As consumption of one commodity increases, the consumption of another commodity also increases. Complementary goods can, for example, be the consumption of water when salty food is consumed. The nature of cross-price elasticity may, amongst other variables, also be dependent on temporal presentation of two commodities. For example, water may be complementary when presented after salty food without salty food being complementary when presented after water. In a similar vein, tennis balls can be substitutable for oranges when it comes to juggling, but not when it comes to eating (see Green & Freed, 1993). This demonstrates that the level of substitutability or complementarity also depends on the context in which choice occurs. Between substitutable and complementary goods are those that are independent. The consumption of one commodity is not affected by changes in consumption of another commodity (as in the case of salty food when presented after water).

Consumption can be affected by reinforcement rate and reinforcer size. However, choice between two reinforcers can also be altered by variables that are independent of the schedule and magnitude of reinforcement (DeGrandpre & Bickel, 1996). Research has demonstrated that both own-price and cross-price elasticity are sensitive to the economic context in which they appear. Similar to elasticity, economic context can be conceptualized to exist along a continuum. At one end are completely open economies with totally closed economies existing at the other end of the continuum. An open economy is an arrangement in which the organism obtains additional amounts of a commodity outside the confines of the experiment. In a closed economy, consumption of the commodity is restricted to the experimental session. Hursh (1980) concluded that it is difficult to formulate a general account of equilibrium (i.e., of supply and demand or cost and effort) in operant behavior without consideration to the total economic system.

Hursh (1980) demonstrated how the economic system strongly determines choice. In a study (Hursh, 1978) in which monkeys worked for the total daily ration of food during experimental sessions, increases in price yielded increasing rates of responding up to very high prices to compensate and maintain a stable intake of food. In a similar study (Catania & Reynolds, 1968) in which food-deprived pigeons were working to obtain a fixed number of pellets during experimental sessions and received additional feedings, demand for food was shown to be very elastic. These findings suggest that the inelasticity of demand demonstrated by Hursh (1978) was a function of the unavailability of food outside the experimental sessions whereas elasticity in the findings of Catania and Reynolds can be attributed to the post-session feedings.

In a closed economy, goods like food, water, and other necessities are presumed to be characterized by a largely inelastic demand. However, feeding experimental subjects between sessions in order to stabilize motivation (i.e., by keeping deprivational operations equal) is hypothesized to open the economy and, indirectly, affect demand. Consequently, increasing the price of a commodity like food produces increased responding in a closed economy but decreased responding in an open economy (Green & Freed, 1998). According to Hursh and Bauman's (1987) analysis, the post-session food provided in the typical open economy functions as a cheap, although temporally distant, substitute for the costly within session food. A closed economy, however, provides no such substitute and responding must, therefore, increase to maintain intake.

Another factor that indirectly affects demand is income. Income can be defined as the amount of funds, goods, or services available to any one individual at any point in time (DeGrandpre & Bickel, 1996). It can be manipulated to reveal differences in elasticity of different commodities (see Hursh & Bauman, 1987). Decreases in income have shown to decrease consumption of commodities that we can label "luxuries" (i.e., the commodity becomes more elastic as income decreases). For example, if a person loses his/her job, that person is less likely to spend money on things such as tickets to movies or concerts, jewelry, and fashionable clothing. Chances are, however, that the person will maintain consumption of food. Food, then, can be labeled a "necessity". In the study by Hursh and Natelson (1981), for example, consumption of EBS decreased as the total income was decreased (i.e., as VI intervals were increased while total length of sessions was held constant). Consumption of food was defended and remained relatively stable as income was decreased. EBS was therefore a 'normal good' in the sense that consumption decreased as income decreased. Conversely, there are 'inferior goods' in which consumption decreases as income is increased. These are important implications that traditional behavioral research has failed to address. Value has typically been considered as either intrinsic to reinforcers or directly related to performance under various schedules independent of more molar context-variables. Additional variables such as economy, income and demand are taken into consideration by behavioral economics.

In behavioral economic studies, income is typically altered by either manipulating the total number of responses that are permitted per session, the total time allotted to a session, or the total number of reinforcers the organism can obtain in a session. Within different economic contexts, the consumer chooses between commodity bundles (i.e., choice constellations) that contain various amounts of two different goods (Kagel, Battalio, & Green, 1995). The consumer can buy more or less of commodity X relative to commodity Y. Price, then, can be changed with or without compensating for changes in the total income. Income-constant price changes occur when the price of one good changes while income remains constant (Kagel et al., 1995). Typically, changes in income produce a parallel shift in demand curves, moving them to the right in the consumption space if income increases and to the left if income decreases (Winger, 1993). In a closed economy, changes in price will automatically entail a relative (i.e., relative in size according to the total effect on possible consumption per unit of time) income-constant price change. Hursh and Natelson (1981) found such an effect in their previously mentioned study in which the rats lived in the experimental chambers. When rats responded for food or EBS on concurrent VI VI schedules of reinforcement in a closed economy, increases in the VI intervals constituted income-constant price changes.

Income-compensated price changes, on the other hand, are defined by an equally large compensation in total income relative to the increase in price so that the original consumption point can be still be obtained. Equal consumption of the reinforcers can, however, be obtained only if all the allotted income is utilized. However, a higher absolute level of cost (or effort) is required to obtain each unit of the reinforcer. This income-compensated price change enables substitution effects to be separated from income effects when two reinforcers are assessed concurrently. A change in consumption under the new set of prices and income reflects the nature of the interaction between the reinforcers and not a change necessitated by the fact that the consumer's real income has been changed (Green & Freed, 1998). Worth noting is income has no or very limited effect in studies where identical commodities are investigated. In concurrent schedules with two perfectly substitutable reinforcers, response allocation will typically follow the rate of reinforcement at the different schedules.

According to the simple law of demand, the consumption of a commodity is inversely related to changes in price (Green & Freed, 1998). As a fundamental concept of this law, demand curves relate consumption of a commodity across different unit-prices. In the behavior analytic literature, unit price is typically conceived as the number of responses that must be emitted to earn a unit of the reinforcer. Some studies founded in behavioral economics have, however, suggested that a fundamental definition of price is a cost-benefit ratio that includes more than a simple number of responses per unit of reinforcer. It is a ratio that specifies the *amount* of work expended per unit of the commodity (emphasis added, Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). Hursh and his colleagues (1988) manipulated fixed-ratio (FR) requirements, number of food pellets delivered, probability of reinforcement, and response lever weight (i.e., effort) in a study with rats as subjects. Unit price, in this study, was comprised of all four factors and was represented by the following equation:

$$UP = \frac{\text{Fixed ratio X lever weight}}{\text{Pellets X probability}} \qquad (2)$$

Hursh and his colleagues (1988) went on to suggest the following equation as a more general term of the components of unit price:

$$UP = \frac{\text{\# of Responses X effort}}{\text{Amount of Reinforcers X value}} \qquad (3)$$

The unit-price can thus be altered by changing either component of the numerator or the denominator (i.e., changes in response requirements and the effort or changes in the number or value of the reinforcing commodity).

In behavioral economics, therefore, the fundamental price factor is not the number of responses required to obtain reinforcers, but rather the number of responses per *unit* of a reinforcer (emphasis added, Hursh et al., 1988). This implies that even if either components of the aforementioned ratio are changed, the price is defined in terms of a predetermined unit. As in the current study, the unit was defined as one cent. Any combination of work requirements and amount of money delivered was labeled in terms of unit prices as the number of responses required per one cent. An advantage of behavioral economics is that the relationship between price and consumption can be quantified through the measure of own-price elasticity (Bickel et al.,1992) and qualitatively different commodities can be compared by assessing cross-price elasticities. With unit price, several factors that are treated as separate independent variables in behavior analysis are subsumed into one independent variable. If the assumptions underlying this concept are valid, this represents a more parsimonious approach to the subject matter.

As an underlying assumption of the behavioral economic theory, consumption should be the same at the same unit price regardless of the compositions of response requirements or efforts and reinforcer values and amounts that make up a given unit-price (e.g., see Bickel et al., 1990, 1991). This implies that when consumption of a commodity is related to the cost of that commodity, different demand curves should be overlapping at similar unit-prices, granted that they have been obtained under similar experimental contexts. The utility of the unit-price concept lies in its ability to quantify the interaction between response requirements and reinforcer magnitude as a cost-benefit ratio and thus allow multiple independent variables to be subsumed into a single variable (DeGrandpre et al., 1993). The notion of unit price has been empirically tested on several occasions both with non-human subjects (Carroll et al.,1991; English, Rowlett, & Woolverton, 1995; Hursh et al., 1988; Lemaire & Meisch, 1984; Winger, 1993; Woolverton & English, 1997) and with human subjects (Bickel et al., 1992). The findings in these studies across different commodities and different species have yielded some contrasting conclusions. Some studies have found that different compositions of unit price yield similar values across unit prices, whereas other have found that the different compositions yield different values of consumption. It is not known what accounts for these discrepant findings. Unit-price has, for example, been found to be sensitive to varying drug doses in behavioral pharmacology research (e.g., Carroll et al., 1991) as well as to the presence of alternative reinforcers (Carroll et al., 1991). Woolverton and colleagues (1997) concluded that the conditions under which unit-price reliably predicts drug consumption need to be delineated. This also seems to be the case with non-drug reinforcers.

In an assessment of the unit-price concept, Carroll et al. (1991) found that when monkeys self-administered phencyclidine (PCP) across different unit-prices with water concurrently available, the demand for the drug decreased as predicted when the price increased. Additionally, different doses of the drug generated overlapping demand curves at the same unit-prices when water was concurrently available, indicating a functional equivalence between drug dose and response requirements. However, when saccharin was substituted for the water as the concurrently available commodity, the demand curves were not as closely superimposed as the demand for PCP was relatively higher at higher doses (0.25 mg/mL) than at the lower doses (0.125 mg/mL) of PCP. Carroll and her colleagues concluded that the elasticity of the demand for PCP was affected by the differences in the concurrently available substitute.

Woolverton et al. (1997) found when monkeys responded at UPs varying from 40 to 10, 000 responses per mg/kg of cocaine, consumption did not adhere to the prediction that consumption should be similar at different compositions of unit-price. Rather, they found, as seen in some previous studies, that consumption at any UP was generally higher at the higher cocaine doses. As mentioned earlier, such findings could be due to an effect inherent in the drug (i.e., a dose effect). This study indicates that the notion of functional equivalence between response requirement and dose magnitude may not hold under all conditions. Foltin (1994) found that baboons responding for food pellets responded proportionally less (i.e., consumption decreased more rapidly) during increases in unit-price when the unit-price composition was of five or ten pellets rather than one. This effect is similar to effects obtained by Carroll et al. (1991) and Woolverton et al. (1997) using drugs as reinforcers. The only difference between these findings is that with drugs as reinforcers, the lack of conformity is observed at unit-prices ratios with higher reinforcer magnitudes whereas with food reinforcers this lack of conformity was apparent at the ratios where the magnitude of the food deliveries were smaller. A question arises whether similar problems will exist with non-drug reinforcers when the reinforcers are altered in size and if this effect will be evident with humans as subjects.

Bickel et al. (1991) conducted a unit-price analysis of cigarette smoking with human subjects. Cigarette smokers pulled plungers on FR 200, 400, or 1600 schedules to obtain 1, 2 or 4 puffs of a cigarette of their preferred brand. As expected, increasing unit-price generally decreased consumption. Additionally, consumption was comparable at the same unit-price independent of the response requirement and reinforcer magnitude comprising the unit-prices indicating functionally equivalent effects between the two variables. A slight tendency towards lower levels of consumption at unit-price compositions with fewer puffs was also evident in this study. This study, along with others lends support to the notion of unit-price as a valuable tool in the analysis of human operant behavior.

Overall, the basic model of behavioral economics has been applied successfully to operant research in drug self-administration. The resulting findings have differed among those that support a unit-price notion and those that do not. Unit-price has also proven to be sensitive to various contextual manipulations. There is some confusion with respect to which factors need to be included in a unit-price analysis and how beneficial this approach is to the experimental analysis of behavior. Furthermore, there have been few studies assessing the concept of unit price conducted with humans as subjects. The studies with humans have assessed drugs as reinforcers (e.g., cigarette studies; for an exception see Tustin, 1994). No studies have assessed money as a reinforcer utilizing a behavioral economic analysis.

The current study was designed to examine demand across different unit-prices and at multiple compositions of the same unit-prices using money as a reinforcer with humans as subjects. The experimental questions raised are whether increases in price would result in positively decelerating demand curves and whether consumption would be similar at different compositions of the same unit prices. Findings from this study will extend the literature on behavioral economic variables with humans. Furthermore, the examination of demand curves with money as a reinforcer will permit an economic assessment of the most widely used non-drug reinforcer with human subjects.

CHAPTER 2

METHOD

Participants

Three experimentally naïve undergraduate students were recruited from introductory classes in behavior analysis at the University of North Texas. The participants ranged from 16 to 42 years old.

Screening

Prior to the onset of the experimental sessions, all the participants completed a brief screening test. The participants were utilized in the experiment if they were able to complete the multiplication table (1x1 – 10x10) twice (no time limit) with no more than 6 errors. The participants also answered questions regarding their physical ability to participate in the experiment and their ability to work independently in a room for a given amount of time. No participants were rejected from the study based on the pre-experimental screening.

Apparatus

A 486 PC was utilized in this experiment. A program written in Visual Basic presented math problems on a monitor. The computer was located in an experimental room measuring approximately 1.70 x 3.00 meters. The room contained no windows except for a one way mirror with blinds (this was not utilized during the experiment).

Math problems consisted of simple multiplication problems ranging from 1x1 to 10x10. A computer keyboard was placed in front of the monitor. The experimenter instructed the participants to use the numeric pad on the keyboard and the enter and backspace keys while solving the problems. Other keys remained operable, however, responses on these keys did not result in any money. In addition, a dark green bar about .5 inch wide stretching from the top left to the top right of the screen denoted earnings from 0 to 600 cents. As the participants solved math problems, the bar increased incrementally when a predetermined number of problems were solved. The number of problems to be solved was determined by the current unit-price. For example, if the current unit-price was UP 4 with a composition of 20 responses per 5 cents, the bar would increase by 1/120 of its total possible length every time 20 correct responses were completed. When the bar reached 600 cents the session terminated automatically. The sessions varied in length according to how many responses were required before $6.00 was earned or how many responses were emitted before the participants terminated the sessions.

The math problems were displayed at the center of the screen with black numbers (Comic Sans font size 72) on a green background. When a correct answer was entered, the next problem was presented. After a predetermined number of correct responses a door bell sound was produced and a counter at the top of the screen registered an addition of either 5 or 15 cents. Earnings in cents were shown at the top of the screen throughout the sessions. The bar at the top of the screen increased in length each time that the sound was presented. After an incorrect answer, the math problem would turn red and remained red until a correct answer was entered.

Procedure

The participants solved math problems, presented on a screen, to earn points that were later redeemable for money. Different amounts of money were delivered for varying response requirements. One correct answer followed by depression of the enter key constituted a response. The unit-prices ranged from UP 1 to UP 20. Unit-price in this experiment was calculated by dividing the number of correct math problems required by the number of cents that were delivered. Thus, unit-price 1 was either composed of a requirement of 5 correct problems solved per 5 cents delivered or 15 correct problems solved per 15 cents delivered. All unit-prices consisted of either 5 - or 15 cent deliveries for varying numbers of correct math problems required.

If the participants did not engage in the problem solving, they were instructed to read magazines that were located on a shelf next to their working station. Reading magazines did not result in any earning~~s~~ of money. When the participants did not depress the enter-key for a period of 3 minutes, the computer program automatically terminated and the participants were prompted by a text-box appearing on the screen to leave the experimental room and get the experimenter. This denoted the end of a session. The participant could choose between two Time Magazines, a People Magazine, and a Cosmopolitan Magazine. Alternatively, the participants could work until a total of $6.00

was earned. Upon earning $6.00 the participants were given the same prompt to locate the experimenter.

The participants completed 15-16 sessions. Typically each participant participated in one session per day. The participants generally engaged in 3-5 days of participation per week. The sequence of the first 10 sessions was similar across all participants. Thereafter, unit-prices yielding intermediate consumption values were replicated within participants. The sequence of unit-price presentations is depicted in Table 1.

Prior to the onset of the first session, the experimenter reviewed the session instructions with the participants. The experimenter pointed to the instructions posted on the wall next to the working station and read the instructions point by point while tracing them with his finger. After reading the instructions, the experimenter asked the participants if they had any questions. Only questions related to the instructional content were answered. The instructions appeared in bullet-point form and were displayed as follows:

Session Instructions

- You have the choice between <u>solving math problems</u> or <u>reading a magazine.</u>
- When you choose to solve math problems, you will hear a sound after a certain number of problems solved and money will be added to the counter at the top of your screen.
- The bar at the top of the screen indicates the total amount of money that you can earn.
- If you would like to take a break, at any time you may read the magazine. If you read for 3 minutes, the sessions will end automatically.

- If you want to end the session, you may at any time stop solving math problems and instead read magazines for 3 minutes.
- The magazines are located on the shelf at the left of your working station. You can choose which magazine you want to read.
- Please, do not engage in activities other than solving problems <u>or</u> reading the magazine.

The instructions remained posted in the experimental room throughout the duration of the experiment.

Following each day of participation, the experimenter would pay the subject the amount of money earned according to that day's performance in cash. Up to $6.00 was paid for each session. If the subject ceased working during a session, the amount paid was relative to the amount of work the participant engaged in during that session. The same unit-price was maintained throughout each session.

When not solving math problems, the participants could read magazines that were located next to the work station. Whenever the participants engaged in reading magazines or did not solve any math problems the current math problem would remain presented on the screen. After 3 minutes of not entering an answer the program would automatically terminate and prompt the participants to leave the experimental room. There were no restrictions on the length of sessions. Sessions were either terminated upon the participants earning $ 6.00 or not responding for 3 minutes. Each participant earned a $ 25.00 bonus upon completion of the experiment and was debriefed about his/her performance and the purpose of the experiment.

The independent variables in this experiment were UPs that were altered either by changing the response requirements or the magnitude of the reinforcer. The dependent variables were the consumption levels and work output. Consumption levels refer to how many cents the participants earned during a session whereas work output refers to the number of math problems solved correctly during the course of a session. Table 1 illustrates the different response requirements utilized in this experiment to earn either 5 cents or 15 cents as well as the total number of responses required for the participants to earn $ 6.00 at the different UPs that were used in this experiment. Note that at UP 20 the response requirement was adjusted from 100 to 99 responses for two of the participants. This was due to apparatus complications during the 100/5-ratio combination. The computer program used in this experiment did not work well with unit-price compositions where the work requirement exceeded 100 responses. During session 5 for participant BC, the computer "froze" and had to be re-started for the session to be completed. 15-cent combinations were not used at UPs from 14 to 20 for the same reason and the indications of responses required to obtain these values are therefore substituted by a line.

CHAPTER 3

RESULTS

Session-by-session consumption values and work output values for the three participants are displayed in Table 2. Consumption was measured in terms of the total number of cents earned per session. Figures 1-3 show the total consumption across unit-prices in the form of a demand curve for subjects WP, BC, and CT. The sessions differed in terms of the amount of cents paid for each response requirement. This is referred to as sessions with either 5- or 15-cent compositions.

Figures 1-3 depict both the individual session data (symbols) and the same data depicted as average values (lines). Each point on the graphs represents consumption at a given unit-price and the graphs include data from all the sessions. Conventionally, demand curves are graphed in double logarithmic units in order to present a clearer picture of elasticity. At a given point on the graph, the absolute value of the slope is called the elasticity coefficient. When the elasticity coefficient is less than 1, demand is inelastic, greater than 1 indicates elastic demand, and equal to 1 indicates unity of demand (i.e., consumption decreases in a one-to-one fashion with increases in price). The own-price elasticity values are plotted at the top of the demand curves. Elasticity is therefore referred to as a point on a demand curve rather than as a whole (see Hursh, 1980). Own-price elasticity coefficients were calculated using the following equation from Samuelson and Nordhaus (1985) (as described in Bickel et al., 1992):

$$\text{Elasticity} = \frac{\text{Delta Q}}{(Q1+Q2)/2} \Big/ \frac{\text{Delta P}}{(P1+P2)/2} \qquad (4)$$

where Delta Q is the change in quantity consumed of a reinforcer, Q1 and Q2 are the quantity consumed under price 1 and price 2 respectively. Delta P is the change in price, and P1 and P2 are the two prices.

All three participants in the current experiment displayed typical performance according to what is referred to as mixed elasticity. In the case of participant WP (Figure 1), total consumption is defended invariably up to UP 14. Elasticity coefficients obtained when applying equation 4 are stated for each participant at the top of the graphs in Figures 1-3 (values given in terms of elasticity of the curve from the previous UP to the next one, hence no values are stated for UP 1). The slope of the curve at UPs 18 and 20 is larger than unity (>1) and is therefore elastic. This graph represents a degree of demand inelasticity that is more severe than that of the other two participants (i.e., in terms of the range of prices at which demand was inelastic, not elasticity coefficients). The demand in Figure 1 drops to its lowest level at UP 20. Participant BC (Figure 2) displayed maximal consumption up to UP 3. Thereafter consumption gradually decreased to values less than 100 cents at UP 20. Elasticity coefficients indicate that demand became elastic at UP 5. Participant CT (Figure 3) defended total consumption at UP 4 and lower. Demand decreased to levels near100 cents at UP 20. Elasticity coefficients indicate that demand became elastic at UPs 4 and 7. These three demand curves, along with the elasticity coefficients, illustrate that demand was elastic at different prices for the different participants.

Elasticity may be a function of several variables and thus vary within a subject's data when initial compositions are replicated. Replications of UPs during the elastic parts of the demand curves in this experiment indicate such variation. Figures 4 – 6 present the consumption data at the different UPs as bar graphs for a better graphical presentation of the obtained values. Generally, identical levels of consumption across UPs with different compositions were found during the inelastic parts of the demand curves. Participant WP's data shows that replication of initial UPs sometimes resulted in lower levels of consumption. This is evident at UPs 14 and 16 where initial values were 600 and 500 cents and decreased to 350 and 400 cents during the second exposure to these UP compositions. The opposite is the case at UP 20, however. At this UP the initial consumption was 115 cents whereas the replicated composition was 300 cents. At UP 18, however, there is a complete overlap of consumption at early and late exposures to 5-cent compositions. There are thus some inconsistencies in terms of consumption generated by early and late exposures to the same UPs. This is also evident in participant BC's data. Initially, total defense of consumption decreased at UP 4 with further decreases in consumption as prices increase. At unit-prices 4 and 5 total consumption was defended when the UPs were replicated in sessions 12 and 13. Consumption at these replicated UP values represents an extension of the inelastic part of this demand curve when considered separately (and not as a total average value) from the other data points at these UPs. For this participant, consumption was higher at later exposures to UPs of either the same composition or with different compositions. The only exception to this finding is found at UP 20 during session 15 with a consumption of 55 cents. This is 15 cents lower than the previous data point obtained at session 5. Consumption at the 15-cent compositions invariably fell at or above the values of the 5-cent compositions. The only major deviance from the average line is found at UP 7 during the first exposure to this price. This occurred during session 2 in which consumption was 105 cents.

Participant CT generally displayed performance that fell relatively close to the average line. Demand reaches 600 cents for both 5- and 15-cent compositions up to UP 4. Demand becomes elastic for the remaining higher UPs. At UP 7 the discrepancies are more profound than at other UPs, ranging from 600 to 320 and 465 cents at sessions 2, 8, and 13 respectively. The 15-cent composition fell at the mean value. At UPs 6 and 20 there is a relatively close proximity between the obtained consumption values. Generally, the early exposures to the different UPs generated higher consumption than the later exposures.

Figures 7 - 9 display the total time spent per session. The dark-colored bars indicate sessions where total consumption was obtained while the light-colored bars indicate sessions where total consumption was not obtained. The data indicate that, for all three participants, time allocated to engaging in the experimental task tended to be close to equal during sessions in which total consumption was not defended. Session duration varies more widely during sessions in which total consumption was defended (dark bars). This is an artifact of the sessions terminating when the participants had earned 600 cents. For WP, the shortest session lasted for a duration of 11 min10 s and the longest session lasted 2 hr 31 min 40 s. Session length for the less-than-total consumption sessions ranged from durations of 52 min 56 s to 1 hr 48 min 2 sec. For BC, the shortest session lasted for a duration of 14 min 26 s and the longest session lasted 1 hr 8 min 42 s. Session length for the same less-than-total consumption sessions ranged from durations of 24 min 28 s to 1 hr 2 min 15 s. For CT, the shortest session lasted for a duration of 11 min 37 s and the longest session lasted 1 hr 31 min 25 s. Session length for the same less-than-total consumption sessions ranged from durations of 36 min 35 s to 59 min 54 s.

Figures 10 - 12 depict the work output functions for participants WP, BC, and CT, respectively. Work output was graphed by plotting the total number of responses per session across UPs. The data are plotted as both total work rates during all sessions (symbols) as well as with average values across all unit-prices (line). All three response output graphs generally display the typical inverted U-shaped curve indicating the break from inelastic to elastic demand at the Pmax value.

Participant WP reached a Pmax at a much higher unit-price than did participants BC and CT. WP (Figure 10) reached a Pmax at UP 16 with a sharp decrease in response output values at higher UPs. The persistent inelastic demand with the resulting high levels of work output resulted in a very short proportion of the downward work output function for this participant. The Pmax was reached at an average of approximately 7200 responses per session yielding an average consumption of 450 cents. The data also show that this participant responded at maximum values up to the breaking point (i.e., Pmax). For participants BC (Figure 11) and CT (Figure 12), Pmax was observed at UP 5 (average of 2325 responses) and UP 7 (average of 3232 responses) respectively. The decrease in response output values at UP 20 was relatively much smaller with these two participants than with WP.

Table 3 displays average response rate (responses/min) at the different UP values from session to session for all three participants. Response rate data indicate that all three participants increased their speed of responding from the early sessions to the later ones. Participants WP, BC, and CT responded at an average of 43.5, 26.6, and 44.4 responses per minute during the first 3 sessions to an average of 60.1, 43.9, and 62.2 responses per minute over the last 3 sessions respectively. This constitutes an average of 38%, 65%, and 40% increases in speed at which math problems were solved correctly from the beginning of the experiment to the end. There were no systematic differences in response rate between long duration (high UP) sessions and in the short duration (low UP) sessions.

CHAPTER 4

DISCUSSION

The main findings from the present study show that over the ranges of unit-prices utilized in this study, mixed elasticity was evident in all 3 participants. Consumption of money for solving simple math problems was inversely related to unit-price. These findings are consistent with previous findings in behavioral economics experiments. However, there were some clear differences in consumption and work rates at different compositions of the same UPs as well as some discrepancies in these values when UPs were replicated at the same compositions in the current study. The reasons for these discrepancies can not be discerned from this experiment.

Behavioral economics has created some new dependent and independent variables. The added emphasis on molar contextual variables as well as the combination of several components into unit price constitute examples of new independent variables. Demand and total work output are “new” dependent variables. According to Hursh (1984):

> The economic approach to behavior typified by emphasis on the demand curve encourages the researcher to view consumption or obtained rate of reinforcement as a major outcome of behavioral adaptation and to focus on the manipulated conditions of the experiment (e.g., fixed-ratio schedule or price, available substitutes, supplemental feeding) as the important controlling variables. Both response rate and reinforcement rate are products of a dynamic adaptation process and it makes little sense to explain the final equilibrium of one in terms of the other. (p. 444)

These explanations of adaptation processes, however, need some empirical support before accepted. One possible piece of supporting evidence for such adaptation can be provided by adherence to the law of demand. The law of demand states that consumption is an inverse function of price (an exception exists in “Giffen goods” where increases in price actually result in increases in consumption of that good to maintain a certain minimum quantity of a “necessary” good). Thus, the adapting organism trades effort for benefit in a lawful way. The lower the effort/cost or the higher the benefit, the more demand increases.

The current study generally demonstrated that consumption of money decreased as unit-prices increased (when looking at average consumption values) and thus supports the adaptation view. For all participants the demand, once elastic, changed in a positively decelerating fashion. The only exception in this study was observed in participant CT when the UP increased from 6 to 7. A slight increase in average levels of consumption was recorded. Overall, these data indicate support for the utility of the behavioral economic concept of elasticity in describing patterns of the consumption of money with human subjects.

Human choice is not only governed by aspects such as the person’s history with respect to that particular commodity, but also by qualitative aspects of the reinforcer (i.e., substitutability) as well as quantitative aspects such as rate, magnitude, and delay of presentation of the commodity. Additionally, variables such as the availability of other reinforcers may also affect choice. In a choice situation, preference can be altered by a shift in absolute reinforcement levels even though no dimension of relative reinforcement changes (Hastjarjo, Silberberg, & Hursh, 1990). Many variables conceived as extra-experimental by typical operant research are included in a behavioral economic analysis. All variables affecting human choice are, however, far from delineated by behavioral economics.

Hursh (1993) stated that radically different sorts of behavioral adjustments occur in open and closed economies. The precise location of the current experimental arrangement along a continuum ranging from open to closed economy is somewhat unclear. Presumably, money should be placed towards the extreme open end (at least in the case of this experiment). Most people have sources of earning money other than what they earn during participation of the research. Imam (1993) stated that in modeling the relative constraints of a particular economy, the proportion of the total consumption that is performance independent is an important factor; the greater that proportion, the more independence exists between behavior and total consumption. In this experiment, the proportion of extra-experimental availability of the reinforcers is heavily skewed towards the open economy. The consumption of money within the experiment may still compete with alternative sources when the cost is sufficiently low relative to benefit. Hence, the importance of money, or 'utility" to use an economic concept, may have varied between participants and affected the elasticity of this commodity.

Some have also argued that substitution based on anticipation of future reward is a key determinant of differences in responding (Hursh, 1980, 1984; Schwartz & Lacey, 1982 as referenced in Timberlake & Peden, 1987). Future rewards in this study may not have been merely in terms of monetary payments. All three participants (who were recruited from introductory classes in behavior analysis) reported that one of the reasons for volunteering and remaining throughout the experiment was to acquire more knowledge about behavior analysis and the experiment itself. Thus, factors like the reinforcing nature of the task, perceived expectations of participating in a research study, and additional access to learn about the subject matter at hand may be factors that affected the rates of responding and thus the overall demand for money in this study.

Additionally, the bonus available at the completion of the study resulted in a further degree of open economy. The participants were informed about the bonus pay prior to the onset of the study. Promise of this money may have produced effects similar to those seen with response-independent reinforcer delivery. In those situations overall rate of consumption during the experimental sessions tends to decrease (see Hursh, 1991; Imam, 1993). The effects of the bonus pay in this experiment remain unknown. The experiment was designed, however, to generate most of the pay that the participants earned as a direct consequence of their performance during the sessions by keeping bonus amounts to a minimum. Staddon (1992), however, pointed out that results from humans earning small sums of money at the end of short sessions are feeble attempts to understand the dynamics of choice compared to studies that look at daily sustenance for a food-deprived animal. On the other hand, it should be pointed out that the importance of findings of basic research are related to their ability to generalize to human choice situations. A complete analysis of money as a reinforcer would require the use of a closed economy.

A demand curve for a given commodity may only reflect the conditions of interactions between the organism and the overall availability of reinforcement at a given point in time. The procedures used in the current experiment with the resulting own-price demand curves increases the ability to delineate the absolute reinforcing effects of money as a reinforcer as opposed to studies with concurrent presentation of two commodities assessing relative value. Note, however, that the current experiment still represents a choice paradigm, despite the fact that no other commodities were concurrently available (except magazines). The participants still could choose to solve math problems for money or not solve problems (i.e. reading).

However, the obtained demand curves may reflect more than only the "utility of money" as a reinforcer for these participants. Compared to what a minimum-wage job would pay, the participants in this study generally worked for low pay in terms of dollars per hour. These relatively large proportions of inelastic demand for money, therefore, seem to indicate that something more than the reinforcing effects of money may have contributed to the consumption levels obtained. The consumption for example, may have been influenced by variables such as perceived "experimenter demand" or the eagerness of the participants to learn about the experiment. Limiting the interactions between the experimenter and the participants, changing the instructions, and de-emphasizing the added benefits for participating in the study may decrease some of the effects of extra-experimental variables. Interestingly, all the participants reported during the debriefing questionnaire that they felt they needed to work either to satisfy the experimenter, because they thought they were supposed to work, or because it was awkward to terminate the sessions. Participant WP did, on occasion, report that she "actually didn't think that the task was so bad" and that she liked to do math. It may be that for this participant, the task itself was automatically reinforcing. Overall, higher rates of responding (and thus higher levels of demand) were observed than anticipated by the experimenter given the work requirements and the amounts of money earned.

Another behavioral economic concept examined in this experiment was that of unit-price. Relatively perfect overlapping of demand curves with different compositions of unit-price would indicate a total agreement with some other studies (e.g., Bickel et al., 1990, 1991; Carroll et al., 1991; Hursh et al., 1988; Woolverton & English, 1995) that have found functional equivalence between reinforcer magnitude and work requirement using reinforcers other than money. However, data in the current study indicate that some of these conclusions about unit-price cannot be directly applied to money as a reinforcer with humans.

Different values of consumption were usually obtained at the different unit prices in this study. All the data points that deviated largely from the obtained average values of consumption in this study, however, were from sessions early in the course of the experiment. For example, WP responded at a relatively low level at UP 20 during session 5, BC at UP 7 during session 2, whereas CT consumed at a relative high level at UP 7 during session 2. It is therefore difficult to discern whether early exposure to UPs had any uniform effects on responding across participants. Within participants, however, WP generally consumed at higher levels during early exposures than later exposures (except at UP 20), whereas CT always consumed at higher levels during early sessions. No such effects may be seen in BC's data. In a similar fashion, both BC and CT displayed higher levels of consumption at 15-cent compositions than that at 5-cent compositions. Several factors may have been responsible for discrepant consumption at replicated UPs.

Discrepancies in the levels of responding at similar UPs across sessions may have been due to within-participant variables that fluctuated from day to day. Unfortunately, due to the logistical constraints of using humans as subjects, no criteria for inter-session stability of performance were set. Extra-experimental variables such as fatigue and deprivation were thus difficult to control. The participants in this experiment showed up at different times of the day, and for participants BC and CT, two sessions were run on the same day on occasions (i.e., in order to be able to finish up faster). If two sessions were run on the same day, they were typically spread apart by several hours. Participant BC, for example, stated that she dozed off and fell asleep during her session 5 (UP 5). This may have contributed to the relatively low consumption obtained at this point. The same participant reported after sessions 12 and 13 (run on the same day) to be “hyper” after reportedly drinking several cups of coffee. Both sessions resulted in full consumption at UPs 5 and 6. These events, and others, may have been extraneous variables that contributed to different levels of responding and consumption. Participant CT reported early on that she “had to finish what she started”. However, the inelastic demand was less for this participant than the other two. An unresolved conceptual issue is how to incorporate variables such as these into a behavioral economics account.

In the same vein, practice effects from engaging in the experimental task were not accounted for in this experiment. There was not enough time and resources to run the different UPs to stability. There were marked increases in rates of responding across the entire experiment for all 3 participants. However, only participant BC showed any indication of higher levels of work output (and consumption) during later sessions. WP showed a slight effect in the other direction. Overall, there seem to be no distinctly uniform or consistent effects of any of the aforementioned variables (i.e., fatigue, how the participants felt from day to day, or practice effects) either across or within participants.

During the post-experimental debriefing both participants BC and CT reported that the amount of time they had available to engage in solving math problems at times was restricted due to other engagements subsequent to the sessions. Both reported that they sometimes had to go to class and at other times they had to go home. BC also needed to go to work on occasions. No such post-session engagements were reported by WP. It may be that some of the demand curves adhered to demand law-like functions due simply to allocation of similar amounts of time to every session. Technically, if a person allotted the same amount of time to participate in the session every time (e.g., one hour), a smooth curve might be the result due to this factor alone (granted that there were no radical increases in rate of responding throughout). Demand would “look inelastic” at the lower UPs and then gradually decrease as the participant would run out of time after one hour. On the other hand, this would also imply that the work output per session would reach a ceiling at the one hour mark and the values would remain the same across different UPs.

Overall, WP’s wide range of session durations indicates limited sensitivity to the time parameter as a restriction on when she would terminate the session. In other words, WP seemed to work for more than one hour whereas the other two participants seemed to limit their sessions to under one hour durations. Session durations for WP tended to decrease from UP 16 to UP 18 and UP 20, indicating that the low level of reinforcement obtained from earning money may have contributed to the time spent in the task. For the other two participants, however, the data indicate some correlation of demand with length of sessions since duration times are limited to up to an hour in both cases. Nevertheless, the fact that the demand curves show decelerating slopes with increasing price and the work output levels vary in an inverse fashion to differences in UPs favors the notion of some sensitivity to the unit-prices for participant BC. Durations decrease from average values of 56 min, 49 min, and 39 min at UPs 5, 7, and 20 respectively. For participant CT, however, there are session duration values from 44 min (UP 6), 65 min (UP7), and 40 min (UP 20) that contradicts sensitivity to money as the primary factor for time and response allocation. This indicates that there may have been some other sources of control determining consumption for this participant.

Furthermore, the debriefing questionnaire revealed that all 3 participants claimed that they would work because it is important to do so when one participates in an experiment. In a related manner, all 3 participants thought that the experiment had something to do with some kind of endurance assessment (no one reported that this conception was due to the instructions). Future research should consider these issues when introducing the experiment to the participants. Also, keeping the interactions between the participants and the experimenter(s) at a minimum may reduce some of the effects of experimenter-participant interactions.

Additionally, the requirement imposed on the participants to terminate the sessions should be scrutinized further. Two of the participants in the current study reported that it was awkward to terminate the session by waiting for 3 minutes. This may have inhibited the participants from quitting sessions at an early stage. The last finding from the debriefing in the current experiment was related to the added value of participating in the experiment. All 3 participants told the experimenter that a main reason for participating and completing the study was based on the availability to the information about the nature and purpose of the study. This could also have affected the elasticity of money. Maybe future participants should be recruited from classes outside behavior analysis and include a screening for people that report that they need money.

The demand curves in this study almost exclusively adhered to the prediction of the law of demand. As price increased, demand decreased. This point lends support to an abundance of previous studies with similar results and it extends the findings to that of money as a reinforcer. Other studies assessing the unit-price notion, however, have been divided between those that support and those that negate this concept. Mostly, these studies have been conducted in behavioral pharmacology and the inability to obtain overlapping demand curves has been hypothesized to correlate with different dose-effects. These differences were hypothesized to be a function of the different direct rate-suppressing effects of these drugs when they were presented in different doses. These effects can, however, be thought to be less of a concern when non-drug reinforcers are utilized to test the unit-price model. The fact that replications generated discrepancies as did different compositions of the unit price with this non-drug reinforcer do suggest that notions of the constancy of behavioral effects of unit price are questionable.

The current experiment has answered some questions and raised others in the extension of the unit-price model to money as a reinforcer. Ultimately, the adoption of the unit-price notion will depend on its utility in research (Bickel et al., 1991) as well as in applied settings. This concept may carry implications for current practices in preference assessment, the determination of work requirements relative to size of rewards, and in typical experimental research to name a few. Behavioral economics stresses the notion that the multiple determinants of behavior act interdependently; that is, unit price describes and integrates what was previously considered to be two functionally distinct operations. Some of these effects were demonstrated in the current study. The elasticity of money as a reinforcer and the concept of unit-price cannot be inferred from consumption and work rates found in this study alone. Other conditions need be assessed. However, with its focus on many contextual variables and its molar analysis, it is apparent that the integration of microeconomics into the experimental analysis of behavior has broadened perspectives on choice and context. Microeconomics is the study of an individual's allocation of resources within a larger system. As such, it is possible to state that microeconomics is macropsychology (Rachlin et al., 1976). Holding macropsychology to be equivalent to behavioral economics, both take on molar analyses and incorporate many new variables that may be useful to behavior analysis.

The utility of the UP concept stems from its ability to quantify the interaction between response requirement and reinforcer magnitude as a cost-benefit ratio. Support for this notion is still pending when using money as a reinforcer. More research needs to be conducted to further delineate the generality of this concept.

APPENDIX A

TABLES

TABLE 1

Response Requirements for 5-cent and 15-cent Compositions
Total Number of Responses to Earn $ 6.00

	5 cents	**15 cents**	**Total responses**
UP 1	5	15	600
UP 2	10	30	1200
UP 3	15	45	1800
UP 4	20	60	2400
UP 5	25	75	3000
UP 6	30	90	3600
UP 7	35	105	4200
UP 14	70	---	8400
UP 16	80	---	9600
UP 18	90	---	10800
UP 20	100 (99)	---	12000

TABLE 2

Sequence of Sessions with UP Values and Compositions

Consumption (C) and Work Output (W) for all Three Participants

Session	WP	C	W	BC	C	W	CT	C	W
1	UP 1 (5/5)	600	600	UP 1 (5/5)	600	600	UP 1 (5/5)	600	600
2	UP 7 (35/5)	600	4200	UP 7 (35/5)	105	746	UP 7 (35/5)	600	4200
3	UP 2 (10/5)	600	1200	UP 2 (10/5)	600	1200	UP 2 (10/5)	600	1200
4	UP 3 (45/15)	600	1800	UP 3 (45/15)	600	1800	UP 3 (45/15)	600	1800
5	UP 20 (99/5)	115	2282	UP 20 (100/5)	70	1400	UP 20 (99/5)	105	2079
6	UP 4 (20/5)	600	2400	UP 4 (20/5)	440	1761	UP 4 (20/5)	600	2400
7	UP 1 (15/15)	600	600	UP 1 (15/15)	600	600	UP 1 (15/15)	600	600
8	UP 7 (35/5)	600	4200	UP 5 (75/15)	435	2176	UP 7 (35/5)	320	2240
9	UP 14 (70/5)	600	8400	UP 3 (15/5)	600	1814	UP 2 (30/15)	600	1200
10	UP 20 (99/5)	300	5940	UP 2 (30/15)	600	1200	UP 3 (15/5)	600	1814
11	UP 2 (30/15)	600	1200	UP 5 (25/5)	345	1725	UP 6 (30/5)	420	2525
12	UP 18 (90/5)	300	5400	UP 4 (20/5)	600	2400	UP 4 (60/15)	600	2400
13	UP 16 (80/5)	500	8000	UP 5 (75/15)	600	3074	UP 7 (105/15)	465	3255
14	UP 14 (70/5)	350	4900	UP 7 (105/15)	390	2731	UP 6 (90/15)	345	2070
15	UP 18 (90/5)	300	5400	UP 20 (99/5)	55	1089	UP 20 (99/5)	100	1981
16	UP 16 (80/5)	400	6400	UP 7 (35/5)	335	2345			

TABLE 3

Average Response Rates (problems/min) across Sessions

	Session	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WP	UP	1	7	2	3	20	4	1	7	14	20	2	18	16	14	18	16
	Rate	38.1	43.2	49.2	49.8	43.2	52.8	54.0	53.4	55.2	55.2	58.8	53.4	60.0	65.5	57.7	57.1
BC	UP	1	7	2	3	20	4	1	5	3	2	5	4	5	7	20	7
	Rate	24.6	25.2	30.0	33.0	29.4	35.4	41.4	40.8	43.2	42.6	36.6	44.4	45.0	43.9	44.4	43.5
CT	UP	1	7	2	3	20	4	1	7	2	3	6	4	7	6	20	
	Rate	37.2	46.2	49.8	49.8	49.8	52.8	51.6	51.6	54.0	52.8	51.0	53.3	54.3	65.9	66.5	

APPENDIX B

GRAPHS

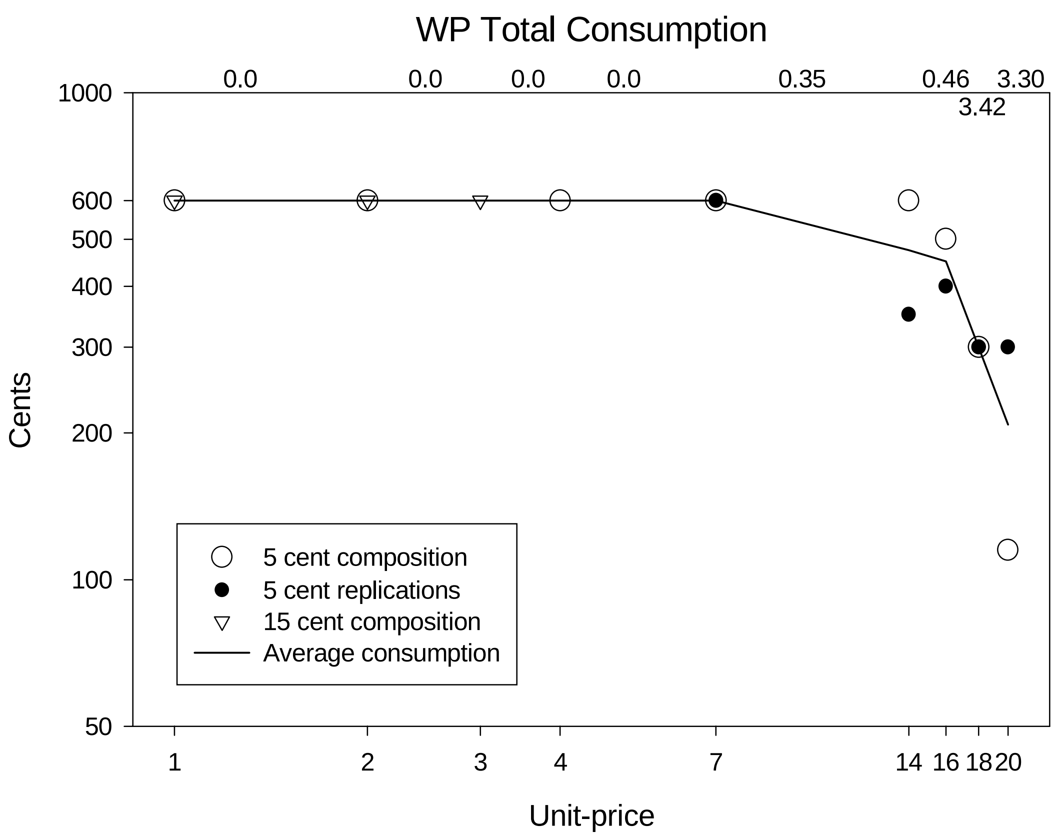

Figure 1. Demand curve for participant WP showing consumption of money at different unit prices in log-log coordinates. Numbers at the top of the graph indicate the elasticity coefficient values at the different parts of the curve. Also shown is a line denoting the average values of consumption at the different unit prices.

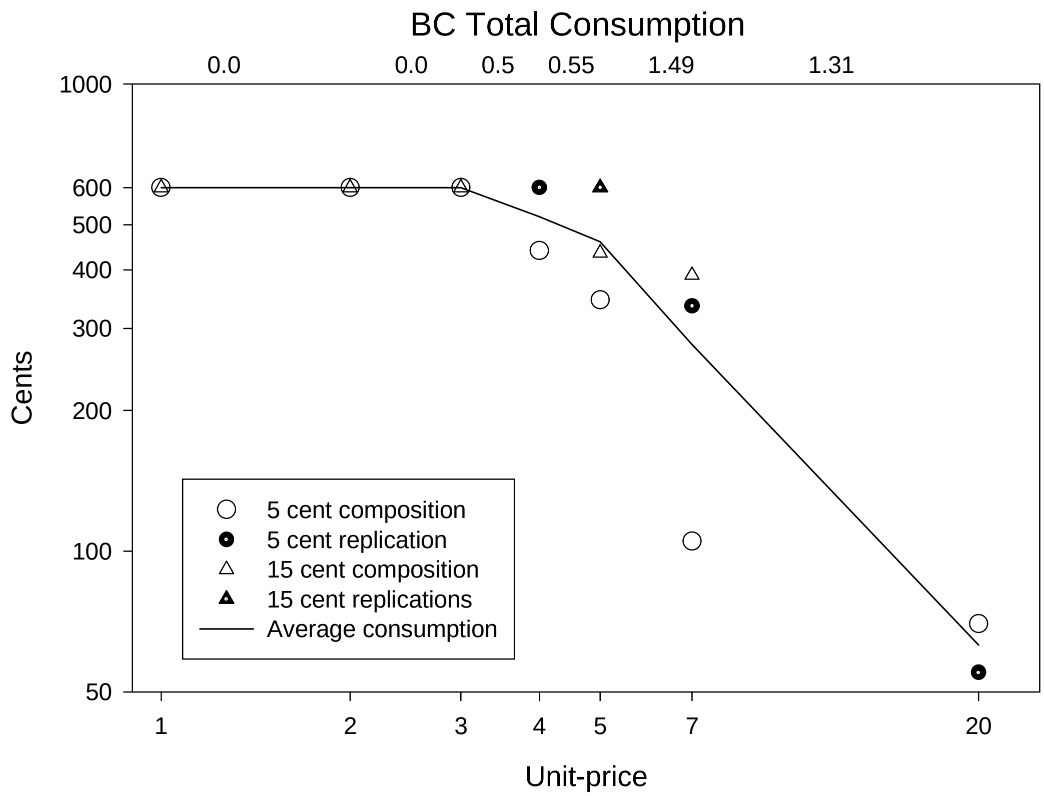

Figure 2. Demand curve for participant BC showing consumption of money at different unit prices in log-log coordinates. Numbers at the top of the graph indicate the elasticity coefficient values at the different parts of the curve. Also shown is a line denoting the average values of consumption at the different unit prices.

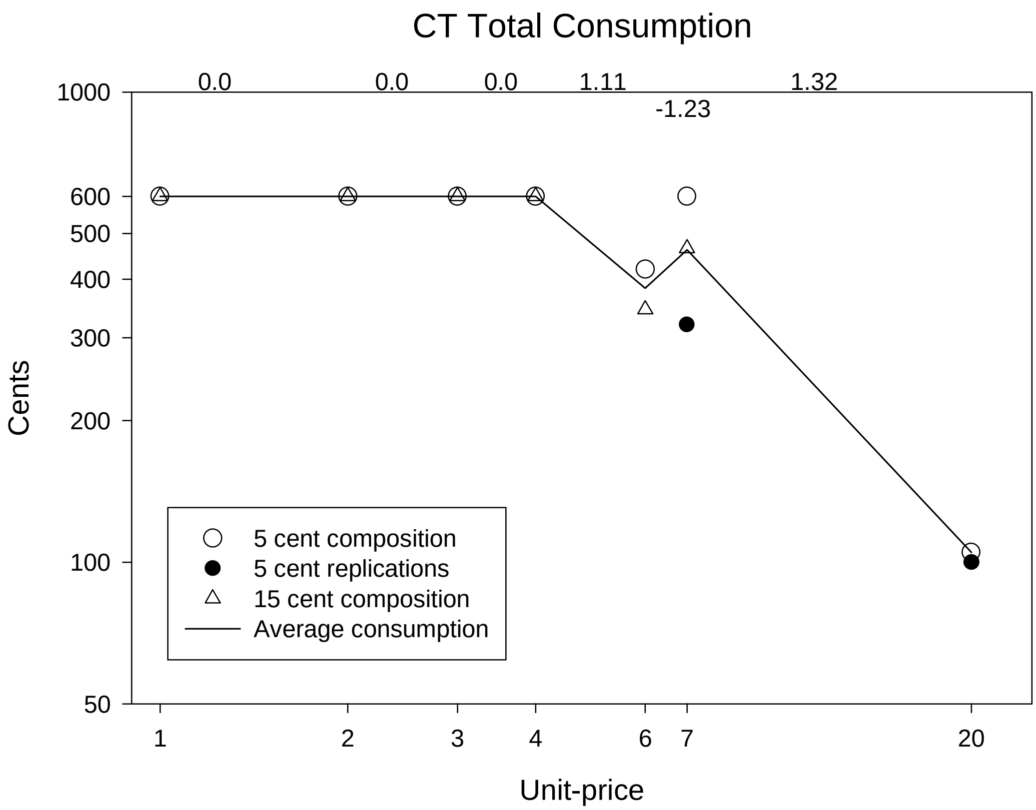

Figure 3. Demand curve for participant CT showing consumption of money at different unit prices in log-log coordinates. Numbers at the top of the graph indicate the elasticity coefficient values at the different parts of the curve. Also shown is a line denoting the average values of cnsumption at the different unit prices.

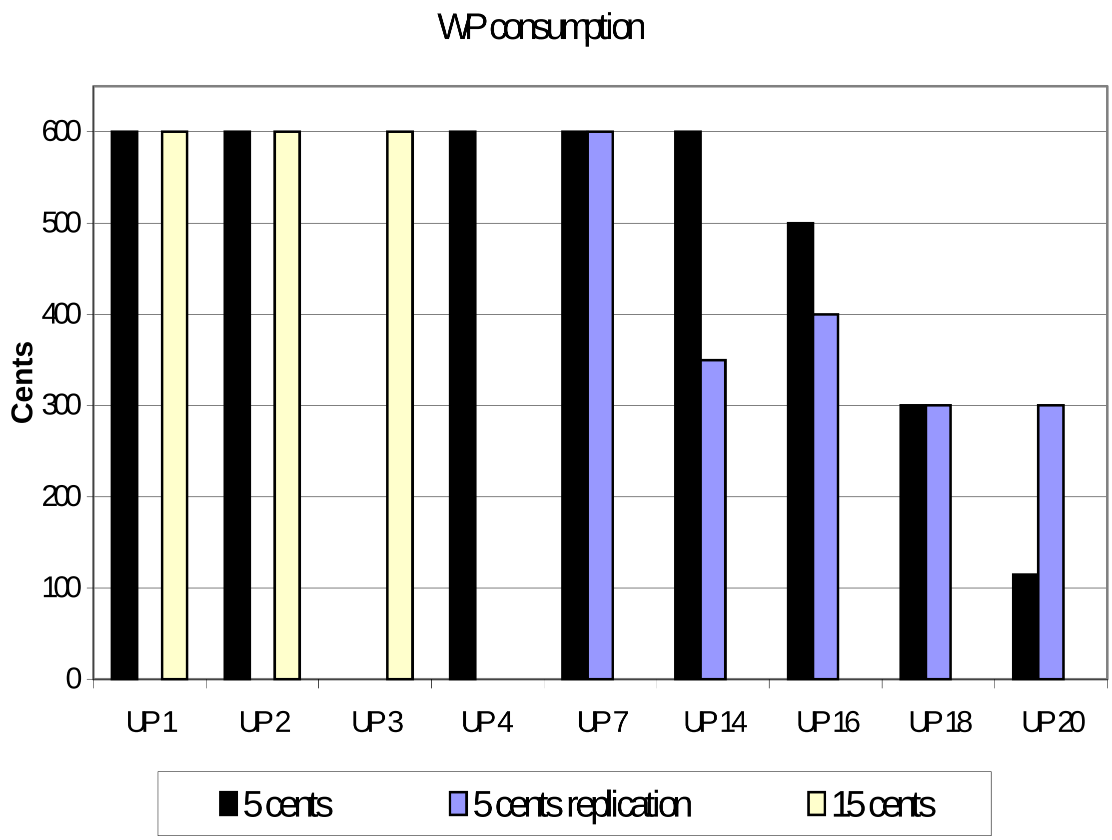

Figure 4. Consumption (cents earned per session) at the different unit prices for participant WP.

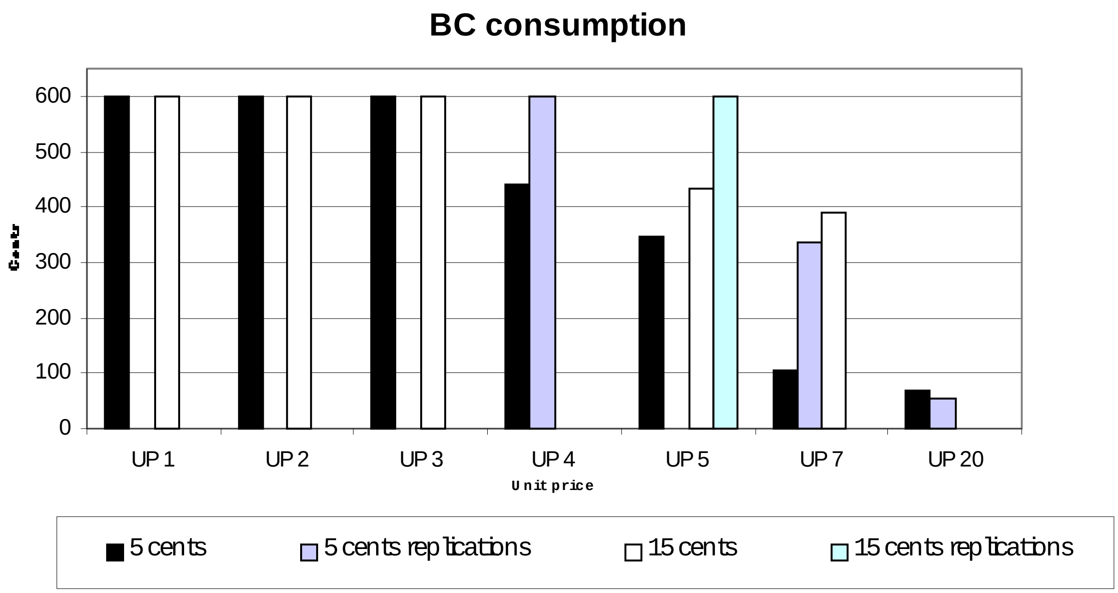

Figure 5. Consumption (cents earned per session) at the different unit prices for participant BC.

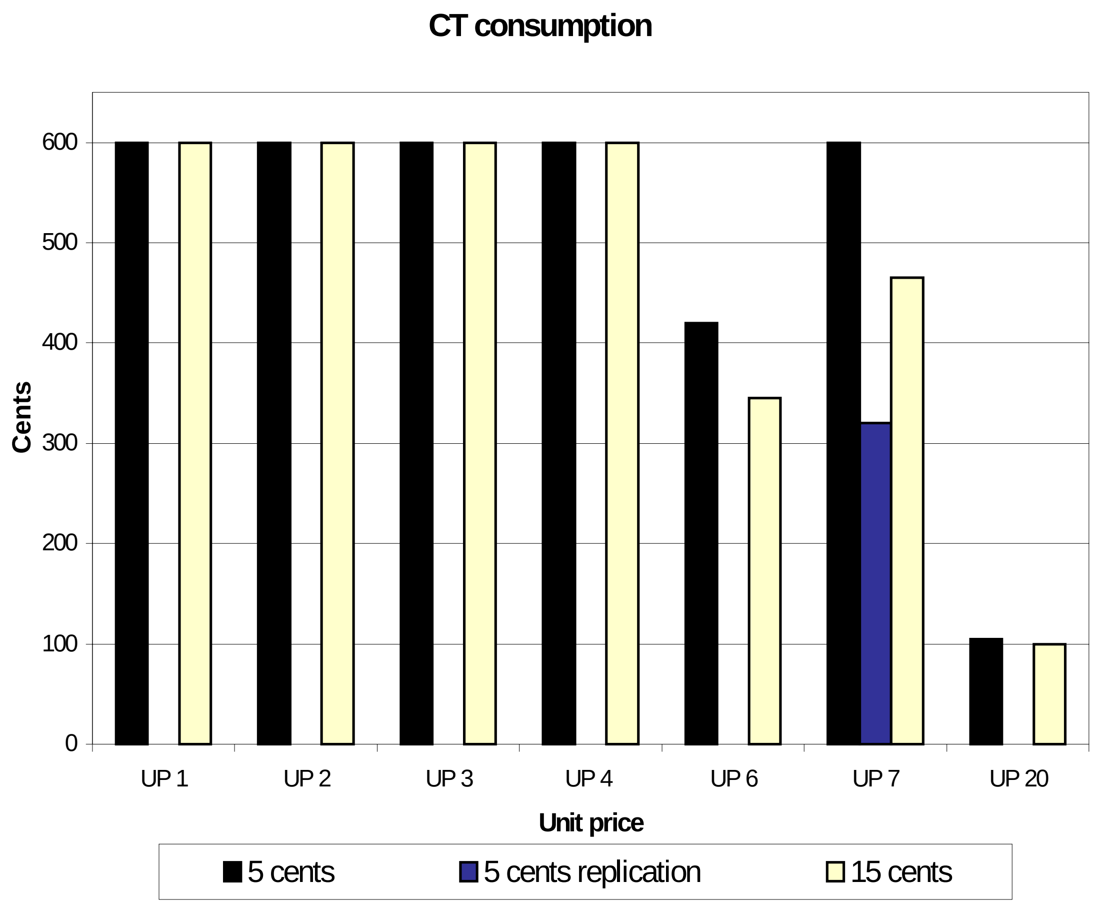

Figure 6. Consumption (cents earned per session) at the different unit prices for participant CT

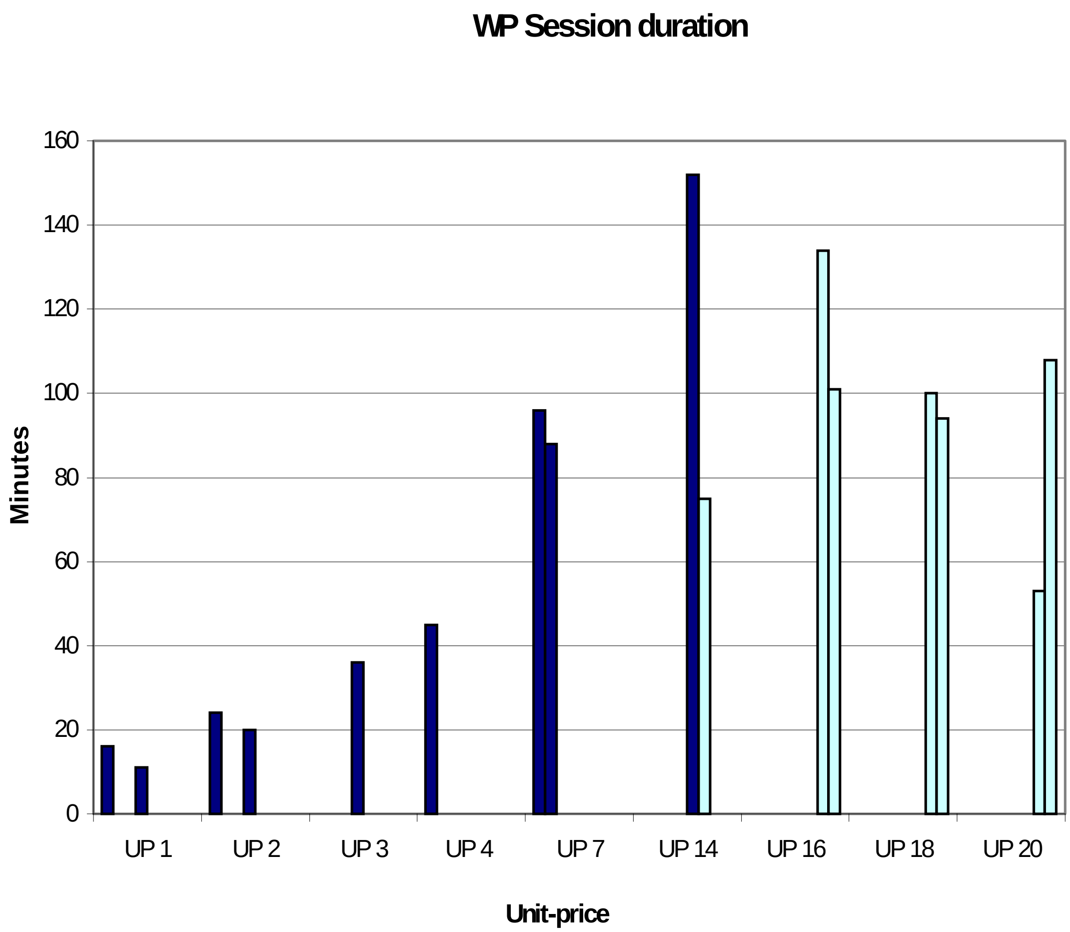

Figure 7. Session durations for participant WP graphed in minutes across different unit prices. Dark colored bars indicate sessions with full consumption. Light colored bars indicate sessions where consumption was less than total.

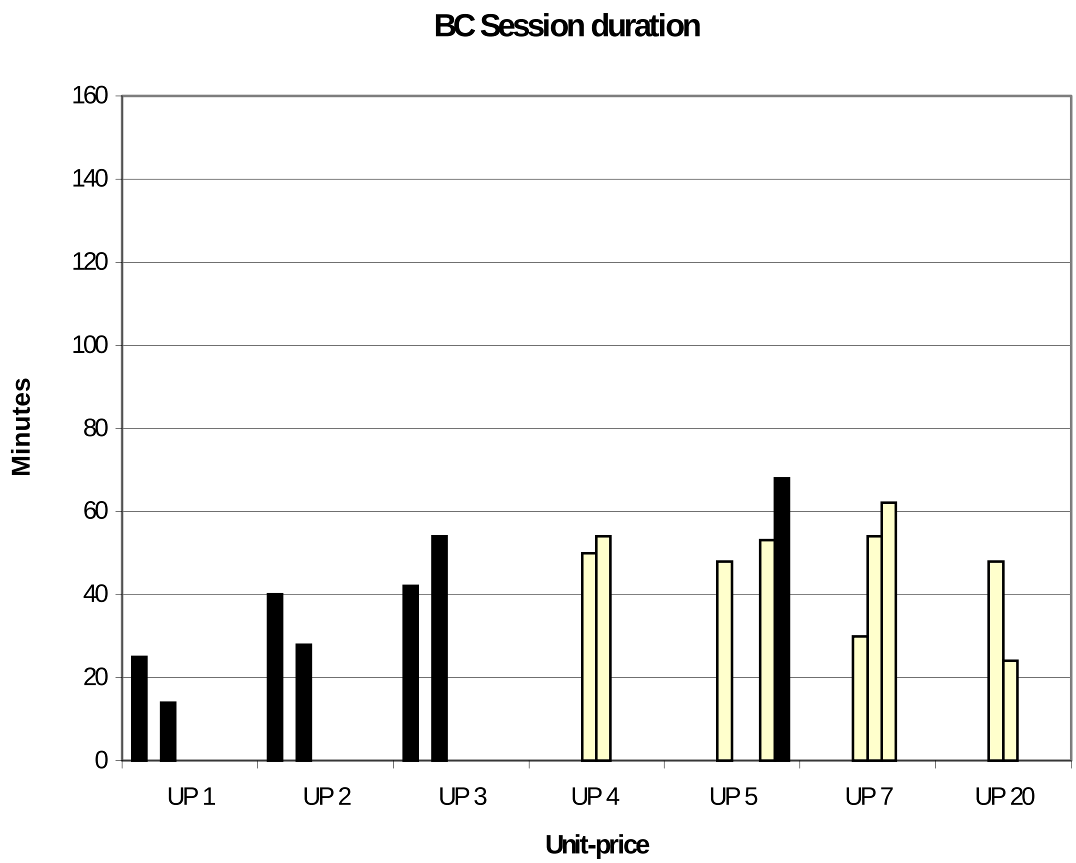

Figure 8. Session duration for participant BC graphed in minutes across unit prices. Dark colored bars indicate sessions with full consumption. Light colored bars indicate sessions where consumption was less than total.

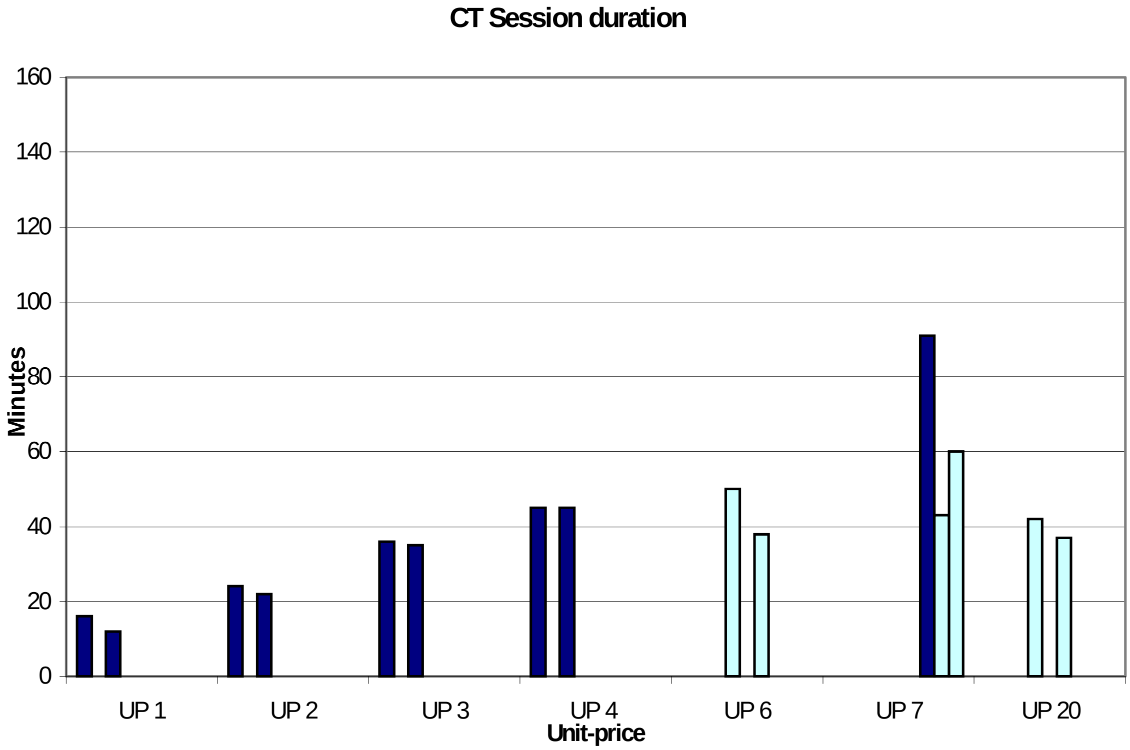

Figure 9. Session durations for participant CT graphed in minutes across different unit prices. Dark colored bars indicate sessions with full consumption. Light colored bars indicate sessions where consumption was less than total.

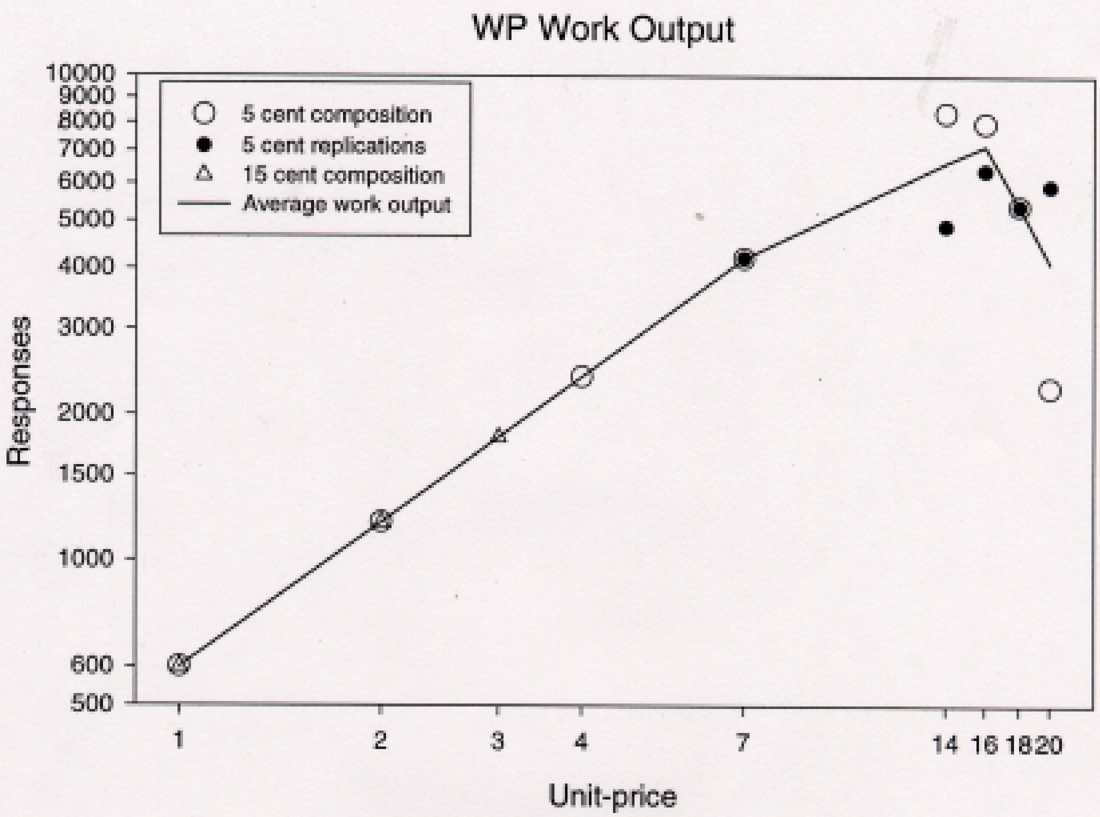

Figure 10. Work output curve for participant WP showing total number of responses per session at different unit prices in log-log coordinates. The line denotes average values of responding per session at the different unit prices.

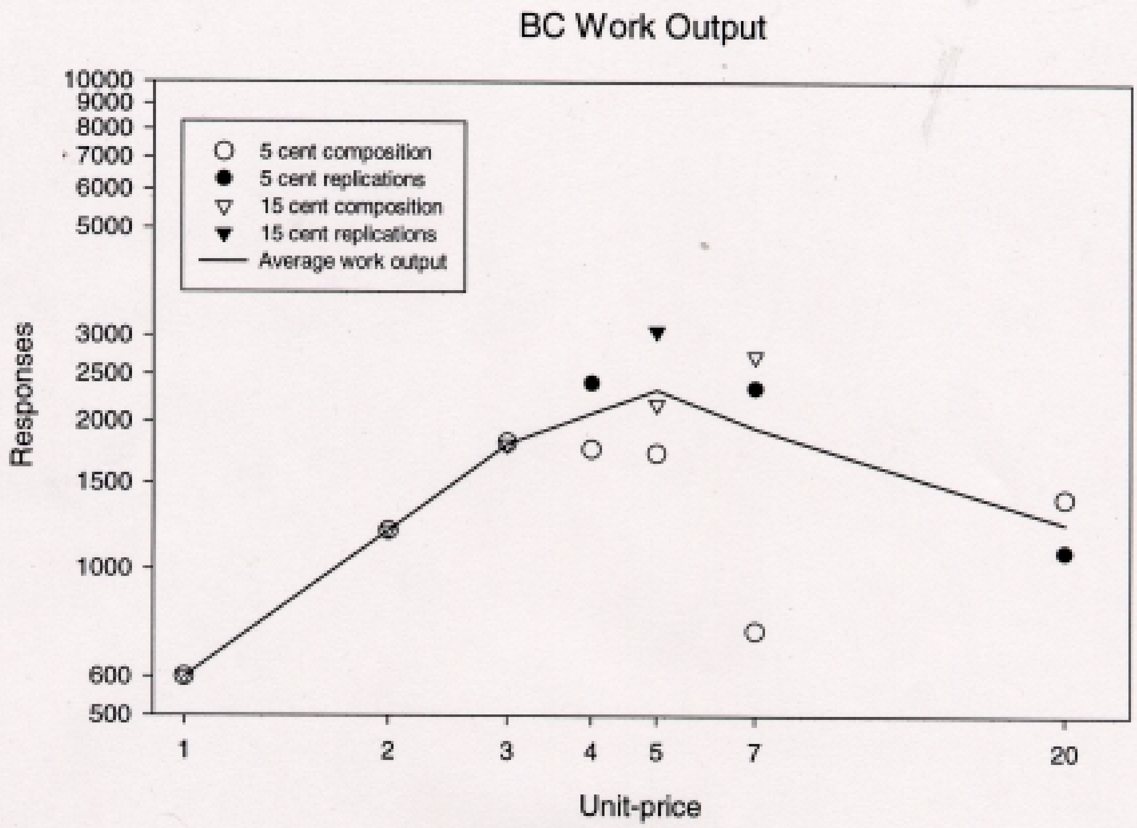

Figure 11. Work output curve for participant BC showing total number of responses per session at different unit prices in log-log coordinates. The line denotes average values of responding per sessin at the different unit prices.

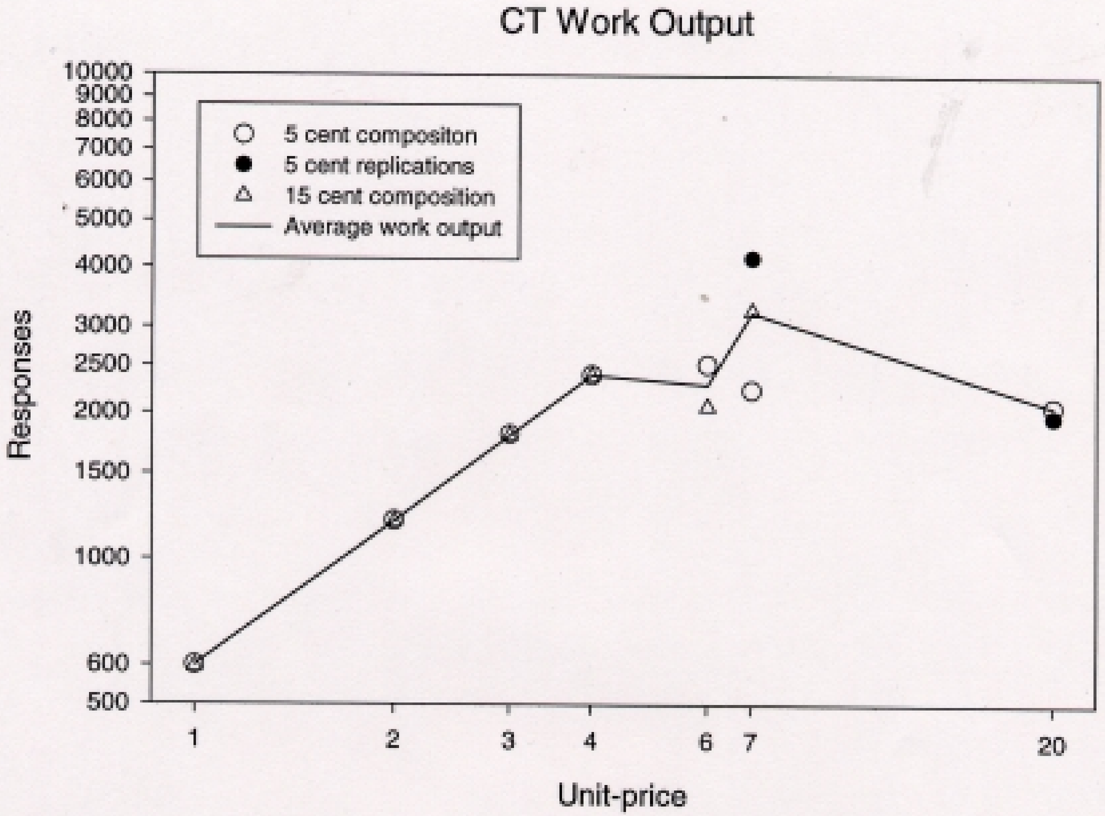

Figure 12. Work output curve for participant CT showing total numbers of responses per session at different unit prices in log-log coordinates. The line denotes average values of responding per session at the different unit prices.

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